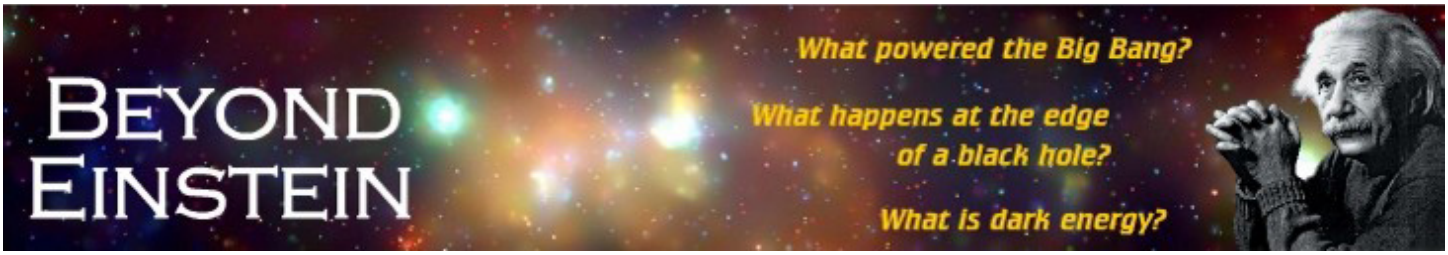


Beyond Einstein: From the Big Bang to Black Holes

Einstein's theory of relativity revolutionized physics and made some startling predictions: that the Universe is expanding from a Big Bang, that black holes so distort space and time that time stops at their edges, and that a dark energy could be pulling space apart. Observations have confirmed these remarkable predictions, yet three profound questions remain unanswered:

- What powered the Big Bang?
- What happens to space, time, and matter at the edge of a black hole?
- What is the mysterious dark energy pulling the Universe apart?

NASA's Beyond Einstein program is the umbrella program for a series of missions designed to address these important questions. The answers could revolutionize physics as we know it today, just as Einstein did a hundred years ago.

What powered the Big Bang?

If the Universe is expanding, it is only logical to assume that at some time in the distant past it must have been confined to a microscopic point of unimaginably high density—the moment of the Big Bang.

In the 1960s, scientists identified a microwave radiation emanating from all points in the sky—the afterglow of the Big Bang itself. Embedded in this afterglow are slight temperature variations that point back to slight density variations in the infant Universe. These variations are the seeds of all the structure we see in today's Universe. We see how gravity has pulled these wrinkles into stars and planets. We can even determine the ratio of matter to energy, the era of first starlight, and the age of the Universe, 13.8 billion years.

What we don't know is: what started it all? We need to coax more detailed information from this ancient light to enable us to piece together the story of how time, space, and energy worked together to power the Big Bang.

What happens to space, time, and matter at the edge of a black hole?

The greatest extremes of gravity in the Universe are the black holes formed at the centers of galaxies and by the collapse of massive stars. Gravity at the event horizon of a black hole is so overpowering that nothing, not even light, can escape its grasp. While black holes are invisible by definition, we can study them by observing their effect on the space around them; we can observe matter spiraling into black holes and we see powerful jets shooting away from them. There is now incontrovertible evidence that black holes exist and are ubiquitous.

Current data hints at general relativistic effects close to a black hole. However, telecopes in operation today are not sensitive enough to tell us exactly what happens at the very edge of black holes. Does Einstein's theory of gravity still hold in these extreme limits? If not, does entirely new physics await us? Einstein's theory also predicted that powerful "gravitational waves" will be released during cataclysmic events such as collisions of black holes. These waves are ripples in space-time itself, predicted but not yet observed. Observations of these waves would be a direct test of Einstein's theory of gravity.

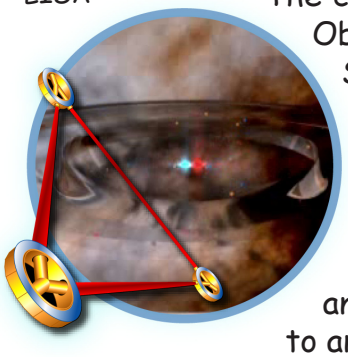
What is the mysterious dark energy pulling the Universe apart?

A landmark discovery of the 1990s was that the expansion of the Universe is accelerating. The greatest mystery in astronomy today is the nature of this force that opposes gravity, which we call "dark energy." Recent data reveals it comprises over 70% of the total mass-energy budget of the Universe. This, combined with the fact that an unknown "dark matter" makes up 25% of the Universe, implies that we do not know what 95% of the Universe is made of! All that we can see with all our telecopes, the myriad stars and galaxies, only make up 5% of the known Universe!!

Trying to understand the nature of this dark energy is one of the most exciting mysteries in astronomy today!

The Beyond Einstein Program

LISA



The central element in the Beyond Einstein program is a pair of Einstein Great Observatories currently in development: Constellation-X and LISA (the Laser Space Interferometer Antenna). Constellation-X will be a powerful X-ray telescope with the sensitivity to observe matter at the innermost edges of black holes. It will also shed light on the nature of the mysterious dark energy. LISA will be a powerful gravitational wave detector that can see collisions of massive black holes. A series of other missions will follow these observatories, designed to answer the exciting questions that will truly take us to an era Beyond Einstein!

Constellation-X

Useful Websites for more information:

- Beyond Einstein website:
  http://beyondeinstein.gsfc.nasa.gov
- Cosmology 101 from the WMAP mission:
  http://map.gsfc.nasa.gov/m_uni.html
- Explanation of science topics from NASA's Imagine the Universe:
  http://imagine.gsfc.nasa.gov/docs/science/science.html
- Answers to commonly asked astrophysics questions are available at the Ask-an-Astrophysicist site:
  http://imagine.gsfc.nasa.gov/docs/ask_astro/ask_an_astronomer.html